View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by College of William & Mary: W&M Publish

WILLIAM & MARY
CHARTERED 1693

W&M ScholarWorks

Reports

8-1-1962

Current Knowledge on the Hydrography and Biology of the Estuarine Portion of James River

William J. Hargis Jr.
Virginia Institute of Marine Science

Follow this and additional works at: https://scholarworks.wm.edu/reports

Part of the Marine Biology Commons

Recommended Citation

Hargis, W. J. (1962) Current Knowledge on the Hydrography and Biology of the Estuarine Portion of James River. Special Reports in Applied Marine Science and Ocean Engineering (SRAMSOE) No. 3. Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.21220/V5DB3P

This Report is brought to you for free and open access by W&M ScholarWorks. It has been accepted for inclusion in Reports by an authorized administrator of W&M ScholarWorks. For more information, please contact scholarworks@wm.edu.

VIMS
GC
1
S67
no.3
c.2

CURRENT KNOWLEDGE ON THE HYDROGRAPHY AND BIOLOGY OF THE ESTUARINE PORTION OF JAMES RIVER

Prepared for the Commission to Study Matters pertaining to the James River

by

William J. Hargis, Jr., Director
VIRGINIA INSTITUTE OF MARINE SCIENCE
Gloucester Point, Virginia

August 1962

Special Report in Applied Marine Science

and

Ocean Engineering No. 3

CURRENT KNOWLEDGE ON THE HYDROGRAPHY AND BIOLOGY OF THE ESTUARINE PORTION OF JAMES RIVER

Prepared for the Commission to Study Matters pertaining to the James River

by

William J. Hargis, Jr., Director
VIRGINIA INSTITUTE OF MARINE SCIENCE
Gloucester Point, Virginia

INTRODUCTION

This discussion of the physical and biological factors operating in tidal portions of rivers like the James has been simplified for clarity and brevity. Every effort has been made to keep the report factual, accurate and complete within limits set by necessity. Greater detail can be found in the articles presented in the reference list.

HYDROGRAPHY OF THE LOWER JAMES

An estuary is that part of a river where tidal and other marine influences occur and where movements of water masses are therefore complicated. In the lower James we are most concerned with that portion of the river extending from Jamestown Island to Hampton Roads (Figure 1).

In the upland portions of the James, an observer sitting on the bank could clearly see that the water generally moves in one direction, downstream, Here the water is well mixed (homogenous) from top to bottom. There is little layering except in very deep pools. The same observer sitting contemplatively on the banks of the estuarine portion of the river would receive a similar impressing of undirectional downstream motion of the water, but this simple impression would be entirely wrong.

If this observer were able to slice the estuary into halves lengthwise and look at the cut portion from the side he would quickly learn that in reality there are two fairly distinct streams situated in horizontal layers, one lying upon the other like layers of a cake. Such a longitudinal section of the estuary is graphically represented in Figure 2. The upper stream or layer, which consists of fresher and therefore lighter water originating in the non-tidal, upstream part of the river, flows seaward. More technically, although there are oscillating tidal movements and laterally-moving eddies, the net flow of this upper layer is downriver or seaward. An object floating on or in this top layer would eventually get to the Chesapeake and then to the Atlantic. The lower layer, consisting of saltier, heavier seawater, flows upstream. It is sometimes known as the salt wedge. An object floating in this layer in the lower Bay would be carried into the river and upstream to about Jamestown Island.

Between these two moving layers, one downstream and one upstream, there is a zone or layer where salt water from below moves up into and is diluted by the fresh water above. The layer in which this vertical movement and exchange occurs is called the "level or layer of no net motion" because here the net flow is vertical (upwards) and not up- or downstream (Figures 2 and 3). In these schematic drawings the "level of no net motion" is that zone where the arrows recurve and there is no net upstream or downstream movement of water. It is indicated hydrographically by an abrupt change from lower salinities to higher salinities below. This salinity change layer is also called the halocline or salt cline. In the James it generally occurs at depths between 10 and 15 feet below the surface. An object of suitable density floating in this layer would move neither upstream nor downstream but would oscillate back and forth in response to tidal movements.

The continuous vertical movement of the salt water across the "level of no net motion" results in the continuous inflow of sea water to replace the sea water that is being diluted and carried downstream by the upper fresh water layer. It is the major engine or pump which drives the entire two-layered system. In this simplified description, no account is taken of lesser hydraulic forces that also contribute to the horizontal movement of water.

In addition to the general vertical, layered situation in lower James there are other interesting details that would not have been suspected from casual observation. If one could slice the estuary in two by a cut from bank to bank and look at the cut end, he would see the two layeres in this cross section (Figure 4). He would note also that the "level of no net motion" or halocline is nearer the surface on the left hand side (northeast bank or Newport News side) of the river looking downstream. Obviously, on this side the fresher surface layer is thinner and the saltier bottom layer is thicker and nearer the surface on this side. The opposite is true on the right hand or southwest bank (Portsmouth Smithfield side) where the surface layer is thicker and extends deeper and the bottom layer is thinner (Figure 3). This difference in the depth of the "level of no net motion" results from the deflecting action of the earth's rotation known as Coriolus force.

Interestingly, the most productive oyster seed bars are along the same northeasterly shore--the left bank facing downstream (Figure 4). Indications are that upwelling water carries suspended materials from the deeper, saltier bottom layer into the "level of no net motion" in the vicinity of these seed bars.

The significance of these physical factors is not clear in detail at present but the obvious close relationship between the upstream-moving bottom layer, the "level of no net motion" and upwelling and the most productive seed beds is undoubtedly meaningful. In other words, the coincidence of suitable seed catching substrate and the currents which bear oyster larvae undoubtedly contributes to the success of this area as a seed-catching area. This subject is amplified below in the discussion on biology of the estuary.

One further characteristic of the hydrographic picture should be mentioned. The salinity of both the surface and bottom layers is higher on the northeast bank (Figure 5) than on the right at any particular transect or cross-section. In other words, waters of higher salinity extend farther upriver on the northeast than on the southwest bank. This is another result of Coriolus force and is related to the smaller volume of fresh water and the occurrence of more upwelling on the northeast side.

As can be seen, contrary to its superficially uncomplicated appearance estuarine circulation, circulation of lower James River, is not simple. Nothing of this circulation pattern was known until careful scientific observations were made. Yet the entire biological productivity, e.g., the success of oyster setting and numbers of fish and crabs supported, of the estuarine portion of the river is dependent upon these factors. These circulation patterns also determine, along with water volume, the amount of contamination that the waters can receive and handle.

According to the best hydrographic information now available, it is clear that a change in the cross-sectional area of the bottom, such as would occur if the channel were deepened from 25' to 35' with consequent widening at the top would result in a change in the amount of salt water flowing into the estuary along the bottom. Salinities in the vicinity of the oyster seed areas would inevitably be increased. The position of the "level of no net motion" would also be changed.

It is not possible to state in advance precisely how much change in salinity would take place at any particular point. Neither is it possible to know at this time what change would be produced in the depth of the "level of no net motion" or in the net upstream flow. Only further hydrographic study of the river itself along with a model study will permit such knowledge and yield the ability to predict hydrographic changes. Salinity, upstream current and the vertical positioning of the "level of no net motion" are all biologically important but the magnitude of importance is impossible to determine at this time.

According to certain authorities there has been an important pertinent recent development in estuarine hydrography (Pritchard, personal communication). Studies of models of other estuaries indicate that each estuary possesses a "Threshold cross section". This may be defined as that cross-sectional area of the river bottom beyond which further increases will produce no appreciable changes in the circulation. Cross section of the river bottom, is of course, directly related to both depth and cross section, not only of natural bottom but also of channels therein. We do not know if the James has reached this critical section as yet. If we did, the Commissions' task would probably be vastly simplified. Only a model study or actual deepening of the river bed or channel will resolve this question. Changes in sedimentation rate and certain geo-chemical balances might be affected also but are difficult to assess at this time.

BIOLOGY OF THE LOWER JAMES

From experience on land it is obvious to all that biological productivity, i. e., the successful spawning and growth of plants or animals, is intimately tied up with the physical conditions of the environment. The same is true in the sea.

What are the effects that these estuarine layers and complex currents and other physical factors have on marine life? Because oysters are the most important commercially exploited marine animal in Virginia waters and because, being sedentary for most of their lives, they must constantly meet the conditions of the local environment or perish, it seems reasonable to use them as an example for explanatory purposes.

As mentioned above and elsewhere, many physical factors, e. g., currents, salinity and temperature, affect the : i) success of spawning; ii) success of setting; and iii) survival of young oysters after setting.

Oysters reproduce sexually. Sperm and eggs are released into the water by adult male and female oysters (sex of individuals changes with age but an individual is either male or female at any one time, not both). This spawning is triggered by environmental conditions and oyster ectocrines. It does not take many adult oysters to produce many millions of progeny.

The resulting young larvae are not able to swim well but are quite dependent on water currents. In other words, they become, during this microscopic stage in their life cycle, part of the plankton. If the prevailing currents are away from good places to set, setting will be poor despite the availability of large numbers of larvae in the water. If the prevailing currents are toward good setting places, chances of successful setting, or spatfall, are markedly improved.

When the young oyster reaches a satisfactory place to establish itself--to set, (suitable substrate is called "cultch"), it throws out a sticky thread and attaches itself to the cultch. As the oyster grows, the downward or attached valve (half of the two-valved shell) is cemented tightly to the substrate. If the oyster larvae matures and does not find a suitable substrate for setting it generally dies in a week or two.

Once the larvae have set they must face many hazards: shortages of plankton--which is their food; diseases such as the fungus, Dermocystidium marinum, and the protozoan, MSX; and, predators like the oyster drills, Urosalpinx cinerea and Eupleura caudata. Poisoning (pollution), smothering (siltation and overgrowth by fouling organisms) and severe competition for planktonic food both from each other and other animals are additional hazards.

The James River has the greatest known oyster seed bed in the world. For years without fail it has produced sets. Seventy to 85 per cent of all oysters produced in Virginia derive from these beds. With this record it is obviously an area where conditions favor spawning, setting and survival of young oysters.

The important conditions favoring setting are suitable currents and suitable setting areas. In this case larvae,probably produced downstream, are swept up toward the setting beds by the upflowing salt layer on the bottom. They are carried by vertical movement into the "layer of no net motion" near the setting areas and are oscillated back and forth over the setting beds by the tidal currents. Obviously, the longer the larvae are held over the potential setting area the more young oysters will set. The oscillation back and forth over the beds in the "level of no net motion" accomplishes this. Upwelling in the vicinity of the seed oyster rocks also probably carries larval oysters to and over these potential setting areas.

In short, it is certain that physical conditions essential to successful setting of oysters now exist in the lower James in the area above the James River Bridge and below Jamestown Island. Should changes in the currents, the "level of no net motion" and the upwelling be caused by possible alterations in the cross section of the river bed (channel deepening), it is quite possible that this excellent chain of physical circumstances would be upset and oyster setting disrupted.

Perhaps more important are the possible results of the alteration of the salinity patterns. These are:

1) It has been agreed by all experts that some changes in salinity in the seed oyster area would result.

2) Should the salinity pattern be changed sufficiently, diseases (quickly) and drills (more slowly) could invade the setting area.

3) At the present time these destructive organisms are kept off the most productive bars by low salinity and associated factors (Figure 6).

4) If these predators, and diseases were present on the producing bars, seed oysters could not survive long enough to be useful to the industry.

Drills and the fungus, Dermocystidium, are located immediately downstream of the most productive bars. Since the last channel studies marine biologists have acquired additional pertinent evidence about effects of salinity. The disease organism MSX, a relative newcomer, actually invades Wreck Shoal, the most productive bar in the setting area, late each year, to be driven out of the oysters and away from the bar by water of low salinity in the spring before appreciable mortality can result. In contrast, Brown Shoal, near the northeastern end of the bridge in waters of higher salinity, once a most productive bar, has been invaded by MSX, and seed production there has drastically declined due to resultant mortalities. As was pointed out earlier there is already an unequal upriver distribution of high salinity waters to the northeastern shore where the most productive shoals are located. If these areas were made still more saline diseases and predators would be able to invade many of these bars.

The extent of changes in the upriver distribution of other marine organisms, e.g., barnacles, shipworm, fishes, crabs, has not been considered. Present knowledge of the ecology and physiology of oysters and their associates (predators and parasites) is more adequate for this type of discussion. Undoubtedly there would be changes in the distribution of other animals and plants, some possibly detrimental, some possibly beneficial.

CONCLUSIONS

It is unfortunate that we do not know enough about biological, physical, chemical, geological oceanography of estuarine areas to make definite predictions at this time about effects of bottom changes.

The only way to predict with assurance what will happen to the salinity and current patterns and the "level of no net motion" in the James River, in advance of actually carrying out the project, would be to construct an experimental model and make the proposed structural changes thereon. This has been done with benefit on other estuaries, for example, the Delaware River and Bay System.

Even after that step has been taken the effects on marine life could be determined only by clear demonstration of the relationship between the currents and "level of no net motion" and the salinity responses of the organism. Though neither hydrographers nor marine biologists have the necessary detailed knowledge at this time to predict in detail the effects of channel deepening, they know enough to be able to recognize and point out these very real dangers, and either or both could do much better were additional information in either or both fields about the James, itself, available at this time. Interestingly enough, both groups of scientists urged more rapid acquisition of this information about the James in 1958, over four years ago.

But this is the present and any decisions to be made regarding this and similar projects will have to be based on present information or information yet to be accumulated.

14 August 1962

List of Publications

and Reports

Pertinent to James River Navigation Project

CORPS OF ENGINEERS. 1956. Report of Public Hearing held in Richmond December 15, 1955, pp. 1-47.

CORPS OF ENGINEERS. 1958. Resume' of statements at meeting in office of District Engineer, U. S. Army Engineer District, Norfolk on October 3, 1958, to discuss the Proposed Model Study of James River and its Possibilities. pp. 1-12.

CORPS OF ENGINEERS. 1962. Review Report on James River Virginia.

GALTSOFF, PAUL S. 1958. A statement by Galtsoff made on February 25, 1958 at the Hearing of the House Committee on Chesapeake and Tributaries of the General Assembly of Virginia in Richmond, Virginia.

HARGIS, W. J. Jr. 1962. History and Current Status of James River Navigation Project. A report to the General Assembly Subcommittee on the James River Navigation Project. pp. 1-12

KAPLOVSKY, A. JOEL. 1961. Estuary Model Tests Expedite Prototype Studies of Pollution. Proc. of the 16th Industrial Water Conference 1961, Engineering Extension series No. 109, Eng. Bull. Purdue Univ., pp. 193-211.

KETCHUM, B. H. 1950. Hydrographic Factors Involved in the Dispersion of Pollutants Introduced into Tidal Waters. Jour. Boston Soc. Civil. Engineers, 37 (3): 296-314.

KETCHUM, B. H. 1951. The flushing of tidal estuaries. Sewage and Industrial Wastes Journal, 23 (2): 198.

McWANE, F. W. 1958. Memorandum of Meeting of Joint Interests on the Development of Procedures for Dealing with Navigation Projects in which Several State Agencies Have Interest, pp. 1-3.